The Central kpc of Starbursts and AGN
ASP Conference Series, Vol. xxx, 2001
J. H. Knapen, J. E. Beckman, I. Shlosman, and T. J. Mahoney

HST Observations of the Nuclear Regions of the Toomre Sequence of Merging Galaxies

S. Laine, R. P. van der Marel and T. Böker

STScI, 3700 San Martin Drive, Baltimore, MD 21218, USA

J. C. Mihos

Department of Astronomy, Case Western Reserve University, 10900 Euclid Avenue,Cleveland, OH 44106, USA

J. E. Hibbard

NRAO, 520 Edgemont Road, Charlottesville, VA 22903, USA

A. I. Zabludoff

Department of Astronomy, Univ. of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721, USA

Abstract. We present first results from an *HST* WFPC2 imaging and STIS spectroscopy program to investigate the structural and star forming properties in the nuclear regions of the Toomre Sequence of merging galaxies. Here we discuss V-band, I-band and Hα images of the nuclei. We comment briefly on the connection between the nuclear morphology of the ionized gas and the merger stage.

1. Introduction

Observational studies of merging galaxies have shown a clear link between interactions and nuclear activity, while dynamical models have revealed the physics driving the radial inflows of gas. Unfortunately, neither ground-based observations nor current simulations are able to accurately follow the evolution of the gas once it reaches the inner few hundred parsecs of the galaxy. Whether the gas flow “hangs up” in the inner few hundred parsecs and forms stars, or continues to flow inward towards a putative AGN has a strong impact on the luminosity and evolution of the merger. Numerical simulations (e.g., Mihos & Hernquist 1996; Barnes & Hernquist 1996) suggest that the nuclear gas dynamics will depend on the structure of the host galaxies and on the dynamical stage of the merger.

To study the evolution of the nuclei in the course of a merger in greater detail, we have acquired *HST* observations of the galactic nuclei in the Toomre Sequence of merging galaxies (Toomre 1977). This is a sequence of eleven systems in progressively more advanced stages of merging, from galaxies in early

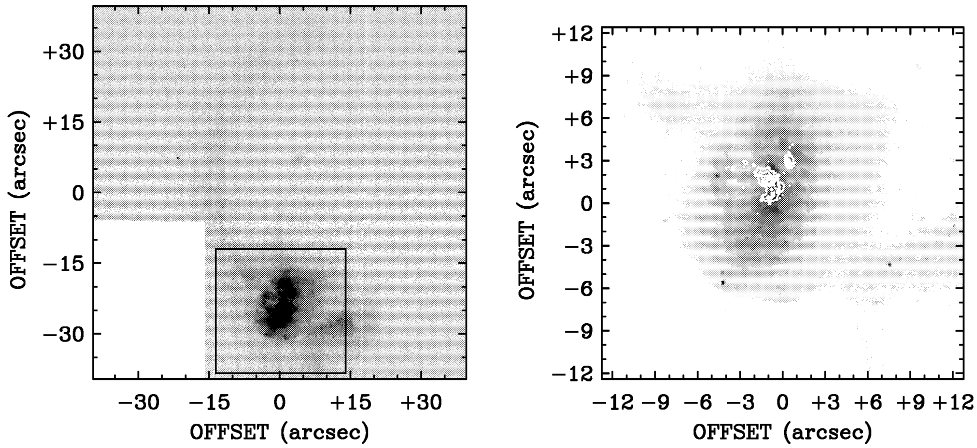

Figure 1. V-band image of NGC 2623 (left) with a rectangle indicating the magnified area on the right which shows the ionized gas disk in Hα emission (white contours).

stages of merging (NGC 4038/9 and NGC 4676) to late stage remnants (NGC 3921 and NGC 7252).

2. Data

We have taken 320 sec CR-SPLIT exposures of each galaxy nucleus using the WFPC2 F555W (V) and F814W (I) filters. The galaxy nuclei were placed on the Planetary Camera chip (0.046 arcsec pixels) to achieve the highest spatial resolution. We also took longer, 1200 sec exposures in the Hα + [N II] lines, mostly through the Linear Ramp Filter (which has $\approx 10'' \times 10''$ arcsec useful field of view). The latter observations allow us to examine the ionized gas distribution.

We will also acquire *HST* STIS spectroscopic data of the same galaxy nuclei. The G750M grating will be used to obtain Hα spectroscopy of the detected ionized gas disks. Three parallel slit positions will be used along the major axis of the gas disks. These two-dimensional mappings will allow us to discriminate between organized and chaotic motions in the gas (e.g. Mihos & Bothun 1998). We will also use the G430L grating to determine the stellar populations in the nuclear regions by comparing the observations to population synthesis models (e.g., Bruzual & Charlot 1996; Leitherer et al. 1999).

3. Project Goals

With the *HST* data we will be in a position to address several important questions regarding the structure and evolution of merger remnants:

1. The morphology of the gas distribution in the innermost kiloparsec of merging galaxies is poorly known. Does the gas settle in a resonance ring (e.g. Hernquist & Mihos 1995) or does it continue to flow all the way to

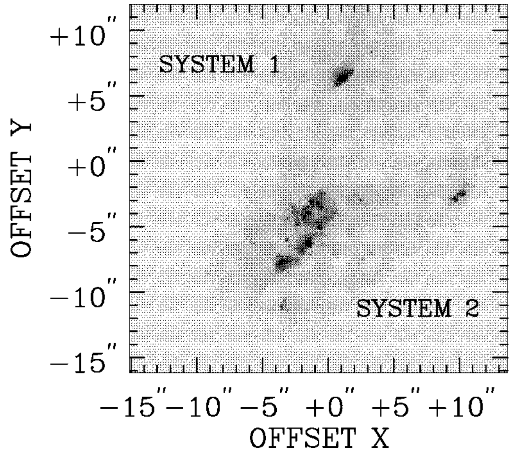

Figure 2. NGC 7592, showing an example of a point-like and a hidden nucleus.

the nucleus, forming a nuclear disk (e.g., Jaffe et al. 1999; van der Marel & van den Bosch 1998)?

2. Since the morphology of the circumnuclear gas distribution is often determined by dynamical resonances, we will look for bars near the nuclei of merging galaxies. Because the resonance locations are partly determined by the rotation curve, we will examine the shape of the rotation curve near the nuclei.

3. We will perform a systematic observational study to determine how the circumnuclear gas kinematics change as the merger advances. Specifically, we will assess whether the gas kinematics become more ordered or chaotic as the merger progresses.

4. Since large amounts of gas are speculated to flow into the nuclear region as the merger progresses, we will look for signatures of supermassive black holes in the nuclei and AGN activity.

5. We will inspect whether the stellar population resulting from a circumnuclear starburst follows the $R^{1/4}$ law. We will also determine at which stage of the merger star formation activity peaks, and also the size of radial gradients of color and line strength in the nuclear starburst population.

4. Early Results

Example WFPC2 images are shown in Figures 1–3. Our preliminary analysis of these data has produced the following results:

1. We have detected nuclear Hα gas disks in six of eleven systems (NGC 2623; Fig. 1, 3256, 3509A, 3921, 4038, 7252). It is perhaps significant that all the four latest stage mergers have nuclear gas disks.

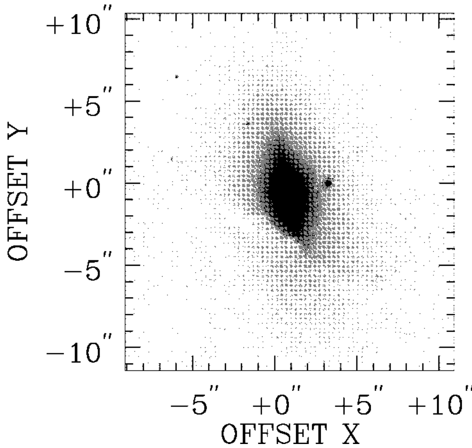

Figure 3. An *HST I*-band image of NGC 6622, showing a bar-like feature around the nucleus.

2. All the five systems in our sample which consist of two clearly identified separate galaxies have one galaxy with a bright, point-like nucleus, whereas the other galaxy has lost the identity of its nucleus (e.g., NGC 7592A; Figure 2). This dichotomy may come from inclination/obscuration effects or differences in progenitor morphological types.

3. Bar-like configurations are seen in a few galaxies (e.g., NGC 6622; Fig. 3). Kinematical data will reveal whether they are highly inclined disks or genuine stellar bars.

Acknowledgments. Support for this work was provided by NASA through grant for project GO-8669 (P.I. van der Marel), awarded by the STScI which is operated by AURA, Inc., under NASA contract NAS5-26555.

References

Barnes, J., & Hernquist, L. 1996, ApJ, 471, 115

Bruzual, G., & Charlot, S. 1996, GISSEL96 Population Synthesis Models

Hernquist, L., & Mihos, J. C. 1995, ApJ, 448, 41

Jaffe, W., Ford, H. C., Tsvetanov, Z., Ferrarese, L., & Dressel, L. 1999, in ASP Conf. Ser. Vol. 182, Galaxy Dynamics, ed. D. Merritt, J. A. Sellwood & M. Valluri (San Francisco: ASP), 13

Leitherer, C. et al. 1999, ApJS, 123, 3

Mihos, J. C., & Bothun, G. D. 1998, ApJ, 500, 619

Mihos, J. C., & Hernquist, L. 1996, ApJ, 464, 641

Toomre, A. 1977, in The Evolution of Galaxies and Stellar Populations, ed. B.M. Tinsley & R.B. Larson (New Haven: Yale Univ.), 401

van der Marel, R. P., & van den Bosch, F. 1998, AJ, 116, 2220